Response to referee #1 (in RC4)

AR: We thank Referee #1 for taking the time to read comments from other reviews and provide such insightful comments. This was very helpful to the discussions that have taken place in the context of this overall review process.

This response by Referee #1 very well illustrates that the uncertainties expected on in situ measurements of the concentration in small ice crystals are still not completely understood and require further efforts and investigations. It is clear that large uncertainties occur in the two first size bins of the 2D-S but arguments such as provided here by Referee #1 seem to indicate that measurements in these bins may not be completely meaningless. This is exactly what has initially motivated us to provide the total ice particle concentrations integrated from multiple minimum size thresholds: 5 μm, 25 μm and 100 μm. As discussed in the manuscript, the absolute values of $N_i^{5\,\mu m}$ are associated with larger uncertainties than those of $N_i^{25\,\mu m}$. However, providing that these issues are clearly stated and discussed, it seems reasonable for $N_i^{5\,\mu m}$ to still be provided to users, who can then make an educated choice on whether or not this quantity is of interest for their studies. Looking at spatial variations in $N_i^{5\,\mu m}$, as mentioned here by Referee #1, are a perfect example of analyses that doesn't require the absolute value to be correct but only the relative changes to be physically meaningful. The results shown in the two parts of this study seem to provide good confidence in the latter point. This comment by Referee #1 has therefore further convinced us that $N_i^{5\,\mu m}$ should not be completely removed from the revised version of the manuscript.

Finally, it is important to emphasize that satellite products of N_i are still at an early stage. They have too rarely been attempted and, most importantly, rigorously evaluated before. It is worth noting that, for this reason, "estimates" has been preferred to "retrievals" to describe N_i in this manuscript. The results presented here, together with the recent studies by Mitchell et al. [2016, 2018], constitute first encourageing steps towards providing more accurate and well understood datasets of N_i to the community. It is evident that DARDAR-LIM can still largely benefit from further improvements - the evaluation presented in this paper has identified several of them and work is in progress in that direction - but this two-part study also presents evidence that realistic and useful N_i values can already be reached. The conclusions drawn here hopefully will serve as motivations for further developments of N_i retrievals from remote sensing measurements.

References:

D. L. Mitchell, A. Garnier, M. Avery, and E. Erfani. Calipso observations of the dependence of homo- and heterogeneous ice nucleation in cirrus clouds on latitude, season and surface condition. *Atmos. Chem. Phys. Discuss.*, 2016:1–60, 2016. doi: 10.5194/acp-2016-1062.

D. L. Mitchell, A. Garnier, J. Pelon, and E. Erfani. Calipso (iir-caliop) retrievals of cirrus cloud ice particle concentrations. *Atmospheric Chemistry and Physics Discussions*, 2018:1–60, 2018. doi: 10.5194/acp-2018-526.